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ABSTRACT

This paper describes the simultaneous effects, including interactions, of two controlled instructional management variables and two student aptitudes on student achievement using a class-means model. Management variables were time allocated for learning with two levels of 45 and 50 class periods, and source of direction with three levels of student-directed, group-directed, and teacher-directed instructional management. Sample consisted of 1108 students from 75 classes taught by 26 teachers. All instruction used an objectives-based modular system developed for teaching high school life science, Individualized Science Instructional System (ISIS), which has been used nationally since 1971. Student aptitudes considered were reading ability and study orientation. Aptitude-treatment and aptitude-aptitude interactions of practical significance were found. (Author/DS)

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Interactive Effects of Source of Direction, Allocated Time, Reading Ability, and Study Orientation on Achievement in High School Science

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Presented to the annual meeting of the American Educational Research Association, Los Angeles, April, 1981.

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Abstract

This study describes the simultaneous effects, including interactions, of two controlled instructional management variables and two student aptitudes on student achievement using a class-means model. The management variables were time allocated for learning with two levels of 45 and 50 class periods, and source of direction with three levels of student-directed, group-directed, and teacher-directed instructional management. All instruction used an objectives-based modular system developed for teaching high school life science which has been used nationally since 1974. The student aptitudes considered were reading ability and study orientation. Aptitude-treatment and aptitude-aptitude interactions of practical significance were found.

This study was based on data from a national field test of the Individualized Science Instructional System (ISIS) conducted during the 1978-79 school year. ISIS is an objectives-based modular system for teaching high school life and physical sciences which has been used nationally since 1974 (Burkman, 1972, 1974; ISIS, Note 1, Note 2). The purpose of the field test was to gain better understanding of the effects of different instructional management approaches and the ways these approaches interact with various student aptitudes.

The student outcome of interest for the present study was achievement on a test covering three ISIS modules or "mini courses." A class-level analysis based on class means of variables was used, since an ultimate goal of ISIS research is to provide advice to ISIS teachers who will use one management approach for an entire class. The analysis included the interactive effects of four independent variables on class achievement. Two of the variables, source of direction and allocated time, were instructional management variables which were controlled in the field test by random assignment of teachers to levels of the variables. "Source of direction" was the source of decisions about the appropriate pace of progress to complete the materials within a specified number of class periods. The three approaches used consisted of decisions by the individual student (student-directed), decisions by small groups of

students (group-directed), and decisions for the entire class by the teacher (teacher-directed). This variable was included in the field test because of suggestions from teachers that some students would benefit from more group activity and teacher direction, even though the ISIS materials had been originally developed to be used independently by the individual student.

Allocated time, the second management variable, was the total time allowed for students to complete the materials and activities associated with three ISIS minicourses, and had two levels of 45 and 50 class periods. Borg (1980), in a review of school learning literature, noted that the effect of allocated time on achievement is usually positive, but that the size of the effect varies widely. An estimate of the allocated time effect specifically for the ISIS materials and students would provide some insight into the possible trade-off between the number of ISIS minicourses covered during a year and the average student achievement for each minicourse.

In addition to the two management variables, the analysis model for mean achievement also included two student aptitude variables to allow the identification of aptitude-treatment-interactions (ATI's). Such interactions, if they exist, are important in the determination of the best instructional management approach for a specific class with given mean aptitudes. The class mean of student reading ability was included as an aptitude because of its obvious

importance when allocated time is limited for working with printed individualized instructional materials. Furthermore, many ATI's associated with such general abilities have been found (Cronbach and Snow, 1977). The second aptitude of study orientation (Brown and Holtzman, Note 3), a measure of study habits and attitudes, was included because of an expected positive correlation with the efficiency with which a student uses allocated time. Thus, it was hoped that the inclusion of both allocated time and study orientation would allow the model to represent implicitly the notion of "engaged time" or time on task, a variable which was not measured directly in this study but which usually is expected to be a more powerful determinant of achievement (Bloom, 1974).

In summary, this study analyzed the interactive effects of two controlled management variables, source of direction and allocated time, and two student aptitude variables, reading ability and study orientation, on the class mean of student achievement on three ISIS minicourses. The resulting description is somewhat restricted in a fashion discussed below due to the impact of subject attrition for two of the management treatments.

Method

Subjects

Twenty-six of the 62 teachers who volunteered to participate in the ISIS field test were randomly assigned to

the six different treatments resulting from the two management variables of interest here. These teachers were located in and around Tallahassee, Florida; Hattisburg, Mississippi; New Orleans; San Diego; San Francisco; and Chicago. The resulting analysis sample consisted of 1108 students from 75 classes taught by the 26 teachers. This sample size was approximately 60% of the group of students who began the field test phase of interest here and who had provided the student aptitude data at the beginning of the school year; the attrition was due to absences during testing periods, student transfers, and lost or incomplete teacher returns. The grade level distribution was: 16% 9th grade, 67% 10th grade, 14% 11th grade, and 4% 12th grade. Fifty-five percent of the students were female.

Instructional Materials

ISIS is intended primarily for students who do not plan to go to college; thus, the science content is practical rather than academic. The three modules or minicourses used in the current study were Keeping Fit, Birth and Growth, and Heart Attack. These minicourses were covered in the second phase of the 1978-79 field test beginning after the Christmas holidays and concluding at the end of March.

A general description of ISIS is given in ISIS (Notes 1, 2, 4, 5). Briefly, each minicourse includes a student booklet featuring learning objectives, instructions for activities keyed to objectives, and self-testing materials.

Most learning activities involve laboratory work and have a semi-programmed format featuring embedded questions calling for overt written response. Activities in each module are divided into three parts; the "core" activities are covered first, "advanced" activities next, and "excursion" activities last. Core activities deal with fundamentals of the subject, advanced activities with advanced topics, and excursion activities with enrichment material. There are two forms of an objective test for both parts. The reading ability level is about grade eight for the core and excursion activities in the student booklet and grade ten for the advanced activities.

Management Variables

The source of direction variable (DIRECT) had three levels, student-directed (SD), small-group directed (GD), and teacher-directed (TD). In the student-directed method the student was expected to work alone as much as possible and progress from one activitiy to another when the student felt ready to do so. Activities could be omitted and the pace of progress and the order in which the activities were completed were decided by the student. Mastery scores set for the core and advanced-excursion portions of individual minicourse tests were the same for all students and minicourses. Students failing to achieve mastery were told to repeat the appropriate sections of the minicourse, and then to retake the test. Only one retest was permitted after which the student proceeded to the next minicourse.

In the group directed method, groups of two to five

students worked together in a group which was kept intact through the three minicourses. The pace of progress was decided on by the group. Exercises were completed collectively and a single group record was maintained. If one or more of the group failed to achieve one of the pre-set mastery levels for a portion of a minicourse test, they were expected to go over the appropriate section of the minicourse again, either individually or in another group, before rejoining the original group. No specific procedures were set for the formation of the group and group structure varied from class to class.

In the teacher-directed method, the teacher set the work pace and made daily assignments for all members of the class. The entire class took each portion of a minicourse test at the same time, but no mastery levels were set and students had no opportunity to continue working on problem areas in that minicourse. All activities in the minicourse were completed by all students in the order they appeared in the ISIS booklet.

The second management variable of allocated time for completion of the three minicourse (TIME) had two levels, the low time (LoT) condition defined as 2250 minutes and the high time (HT) condition of 2500 minutes. Teachers translated these times into class periods based on class length. Thus, for 50 minute class periods, the LoT and HiT conditions were 45 and 50 class periods respectively. Adjustments were made for time lost due to assemblies, etc.

Achievement and Aptitude Variables

The outcome of interest in this study was the class mean of student achievement (ACHIEV) on a final test for all three minicourses. The achievement test, administered under standard conditions at the end of the allocated time for the three minicourses, consisted of 59 multiple-choice items selected at random from the individual minicourse tests. The reliability (Alpha) for this test was 0.88.

Both of the student aptitudes, reading ability (READ) and study orientation (STUDY), were measured with instruments adminstered under standard conditions at the beginning of the school year. The reading test consisted of ten passages of at least one hundred words each which were selected at random from the ISIS minicourses used in the study. Cloze tests of ten items for each passage were combined to form a 100 item test with a reliability (Alpha) of .96. Test development procedures were those discussed by O'Reilly, Schuder, and Kidder (Note 6). The study orientation variable is an overall measure of study habits and attitudes which combines four subscores assessing promptness in completing assignments, use of effective study methods,student opinion of teachers and their methods, and attitudes toward educational objectives and practices (Brown and Holtzman, Note 3). The 100-item test had a reliability (Alpha) of .94 for this study.

Study Treatments

The relationship of student achievement (ACHIEV) with

the two management variables of source of direction (DIRECT) and allocated time (TIME) and the two student aptitude variables of reading ability (READ) and study orientation (STUDY) can probably best be described by comparing ACHIEV on READ and STUDY relationships across the six different management "treatments" formed by combining the two management variables. Remembering that the source of direction variable consists of the student directed (SD), group directed (GD), and teacher-directed (TD) approaches while the allocated time variable has two levels of low time (LoT) and high time (HiT), the resulting six study treatments can then be designated "student directed/low time" (or SD/LoT), etc.

The model used for all descriptions in this paper was based on data from all six DIRECT/TIME combinations or treatments. The descriptions themselves, however, are limited to contrasts among only four of the treatments. Two treatments, the SD/HiT and GD/HiT combinations, are not included in the present description because of severe restriction of range problems resulting from subject attrition. The means and standard deviations for the achievement and aptitude variables with class as unit of analysis are shown in Table 1 for each treatment. Given the relatively small number of classes in the study, the variability of the aptitude sample statistics across the treatments seems reasonable for all treatments except the two mentioned above. When the SD/HiT and GD/HiT treatments are dropped as untrustworthy, the final descriptions of the effects

of the management variables are restricted to the following contrasts: effect of source of direction for the low time condition (the SD-GD, TD-GD, and SD-TD contrasts for the LoT condition) and the effect of allocated time for the teacher-directed approach (the LoT-HiT contrast for the TD approach).

Insert Table 1 about here

Analysis Procedure

The decision about which interaction terms were to be included in the final analysis model was based on a judgement of practical significance, not on statistical significance, following recommendations by Cronbach (1975). Briefly, the rationale for such an approach first recognizes that very large sample sizes are required to provide adequate statistical pwoer for the detection of important interactions (e.g., Cronbach and Snow, 1977). Thus, many researchers who wish to study interactions find it impossible, because of limited resources, to work with "required" sample sizes. Interaction studies of adequate power will be especially rare where the appropriate unit of analysis is an aggregate (like class), as in the current study. Cronbach (1975) pointed out that the conventional use of statistical significance testing under such conditions will virtually guarantee that important interactions will be ignored, resulting in over-simplified models and descriptions. Cronbach argued, instead, for the direct description of the full complexity of the study results,

without imposition of an initial significance testing "screen". The researcher would then focus on features of practical importance using interval estimation to indicate the relative degree of trustworthiness of each feature. Of course, it is very possible that some of the features in such a description will be due entirely to chance. It is hoped, though, that important interactions will be confirmed in the long run by the identification of interactions which emerge consistently in such detailed descriptions over a series of quasi-replications. Thus, the approach used here should provide a better chance of describing important interactions in the long run at the expense of a greater risk that features in the current description may be due to chance.

The model for the current study was specified, then, by first considering the effect of the most complex interaction possible, the four-way interaction among the four independent variables. The R^2 increment due to this term was only .01 with a p of approximately .15, but the term had an important impact on the interaction patterns in the final description. Therefore, this and all lower-order interactions were retained in the model. This model ensured the optimal interactive fit of ACHIEV on READ and STUDY for each of the treatments. Interval estimation procedures associated with the general linear model (e.g., Graybill, 1976) were used for the inferential aspect of the description of treatment effects. These

inferential results should be viewed as approximate due to probable violation of the assumption of independence; teachers, each with two or three classes, were randomly assigned to the treatments, but class was used as the unit of analysis.

Results

The general model for the student achievement class mean (ACHIEV) with independent variables of source of direction (DIRECT), allocated time (TIME), class mean of student reading ability (READ), and class mean of student study orientation (STUDY) decomposes into the separate ACHIEV on READ and STUDY models shown for each of the four DIRECT/TIME combinations in Table 2. The coefficient of determination, R^2, for the different models within each treatment ranges from .70 to .93. The overall R^2 and standard error of estimate for the general model including the management variables are .80 and 5.4 respectively.

Insert Table 2 about here

Estimated class achievement means for each of the four treatments of interest are shown for several combinations of the READ and STUDY aptitude variables in Figure 1. The aptitude combinations were selected to approximately represent the range of aptitude class means common to all treatments. Note that the specific READ and

STUDY values determine the relative locations of the individual figures in Figure 1. Thus, moving from left to right across the top two or bottom two figures corresponds to a change in READ from 40 to 70 for a constant STUDY value, while moving from the bottom to the top corresponds to a change in STUDY from 60 to 110 for a constant READ value. This arrangement makes it easy to consider the effects of one aptitude, holding the other aptitude constant. For example, the estimated achievement for each treatment always increases when moving from left to right across the top two or bottom two figures; that is, the effect of reading ability on achievement is always positive. The study orientation effect is also positive for most conditions shown, except for the negative effect in the TD/HiT treatment for low READ values. The strength of the READ and STUDY effects ranges from very weak to very strong depending on the specific values of the other variables.

Insert Figure 1 about here

The effects of source of direction and allocated time are also represented in Figure 1 by appropriate differences among specific estimates for a given aptitude combination. Two general conclusions are clear for this figure: some of the estimated effects shown are of practical importance (i.e., they are equal to or larger

than the standard error of estimate of approximately five ACHIEV points), and the size of the effects varies widely with variation of the aptitudes (i.e., there are ATI's of practical importance). The precision of the estimates of the various treatment contrasts represented in Figure 1 is indicated by the 90% simple confidence intervals shown in Table 3. In general, the interval widths become larger with increasing deviation from central READ and STUDY values. The interval widths are relatively large for the larger estimated effects, indicating that exact contrast values are not known with much precision. The widths are still small enough in a number of cases, however, so that there is little question about the direction of some effects. Hypothesis test conclusions for $\alpha = .10$ (assuming test-wise α) can be obtained by noting that a point estimate larger in magnitude than the interval half-width implies statistical significance.

Insert Table 3 about here

The variation of the management variable effects with changes in the aptitudes can be described more precisely by plotting constant contrast contours in the READ-STUDY plane. Figures 2-4 present results for the source of direction variable (i.e., the SD-GD, TD-GD, and SD-TD contrasts for the LoT TIME condition), and Figure 5 shows the allocated time effect represented by the LoT-HiT contrast for the TD approach. In addition to the constant

contrast contours, each figure also shows the sample aptitude data for the two treatments in the contrast. Attention should be directed primarily to the READ/STUDY region in each figure which contains data from both treatments; contrast estimates outside of this region are based on extrapolation and should be viewed as very uncertain.

Consider first the variation of the estimated SD-GD contrast shown in Figure 2. The student-directed (SD) approach is estimated to be superior to the group-directed (GD) approach throughout the entire READ/STUDY region spanned by data from both treatments. The extent of superiority is 10-12 ACHIEV points in the middle of the region, a difference which is of practical importance. The corresponding confidence interval in Table 3 suggests a high degree of certainty about the direction of this effect. The smallest SD-GD differences of five points or less are found in the low READ/low STUDY and high READ/high STUDY regions, while the largest differences approaching 15 points are in the low READ/high STUDY and high READ/low STUDY regions.

Insert Figure 2 about here

An alternate way to characterize the contour patterns in Figure 2 describes the effect of one aptitude holding the other aptitude constant. For example, imagine a

vertical line located at a reading ability of 40. As study orientation is increased along this line (i.e., as we move up the line), the vertical line intersects contrast contours for larger and larger positive SD-GD differences. That is, the effect of STUDY on the relative superiority of the SD approach is positive for low READ values. In contrast, the same STUDY effect is negative for high READ values. Consideration of the intersection of horizonal lines with the contours indicates that the effect of READ on the relative superiority of the SD approach is positive for low STUDY values and negative for high STUDY values. These reversals reflect the effect of the DIRECT by READ by STUDY interaction in the analysis model.

Contours for constant values of the TD-GD contrast for the LoT condition are shown in Figure 3. The teacher-directed (TD) approach is estimated to be superior to the group-directed (GD) approach throughout the entire region, but the extent of superiority is modest at best, not reaching 10 points in the region containing data from both treatments. The relatively small variation of the estimated contrast which does occur in the center of this region is a function primarily of READ changes. The direction of the READ effect on the superiority of the TD approach for constant STUDY values is positive.

Insert Figure 3 about here

The estimated SD-TD contrast (the remaining pairwise contrast in the source of direction variable) is shown for the LoT condition in Figure 4. In the READ/STUDY region spanned by data from both treatments, the student-directed approach is generally superior to the teacher-directed approach. The size of the difference ranges from zero to a modest five points along a diagonal running from low READ/low STUDY to high READ/high STUDY. Larger differences ranging up to approximately 10 points are found, however, for the low READ/high STUDY and high READ/low STUDY regions. Figure 4 exhibits a reversal of the individual effect of each aptitude due to the DIRECT by READ by STUDY interaction which is similar to the pattern for the SD-GD contrast in Figure 2. That is, the effect of READ on the relative superiority of SD over TD is negative for high STUDY values and positive for low STUDY values, while the effect of STUDY is negative for high READ values and positive for low READ values.

Insert Figure 4 about here

Finally, contours of constant values of the LoT-HiT contrast (the only contrast in the allowed time variable) for the TD approach are shown in Figure 5. The widely spaced contours with small slope indicate that STUDY is more important than READ in the variation of the contrast. In general, the HiT condition is superior for low values

of STUDY, and the LoT condition is superior for high STUDY values. Magnitudes of differences approach 10 points and more for the extreme STUDY values. Within this context, the relative HiT effectiveness increases slightly with increasing READ.

Insert Figure 5 about here

Summary and Discussion

Both management variables, source of direction and allocated time, produced effects on the class mean of achievement which were of practical significance and trustworthy in direction. For the source of direction variable, the relative order of superiority in general of the three approaches considered was: student-directed, teacher-directed, and group-directed. The general superiority of the student-directed approach is consistent with the original ISIS premise that an individualized approach could be more effective than traditional teacher-centered approaches for the content and students of interest. This same premise has also been supported by several previous ISIS studies (Burkman and Brezin, Note 7; Burkman, Brezin, and Griffen, Note 8).

The relative inferiority of the group-directed approach to both the student-directed and teacher-directed approaches was somewhat suprising to the authors. It was

anticipated that the group-directed results would be intermediate, since this approach combined aspects of both the student-directed and teacher-directed approaches. Two possible post hoc explanations are that the time and energy required to maintain group cohesion and direction cut too far into the time required for learning, and that social activities in groups often composed of close friends might have interfered with learning.

Ordinal interactions between the source of direction variable and the class means of reading ability and study orientation produced variations in the contrasts among the three approaches which were of practical importance. For example, the estimated superiority of the student-directed approach over the group-directed approach varied, depending on the READ and STUDY values, from a negligible difference up to approximately 13 points. The effects of reading ability and study orientation on the contrast of the student-directed approach with both the group-directed and teacher-directed approaches were the same for both contrasts (i.e., for both Figures 2 and 4). In each case, a DIRECT by READ by STUDY interaction produced effect reversals. The effect of reading ability on the superiority of the student-directed approach was negative for high values of study orientation and positive for low values, and the effect of study orientation was negative for high values of reading ability and positive for low values. This

effect reversal was not anticipated. Instead, conventional expectations that achievement on ability slopes are smaller for individualized treatments than for teacher-centered approaches led the authors to expect a negative effect of reading ability on the superiority of the student-directed approach. Also, the expectation that study orientation would be strongly related to a student's ability to use allocated time efficiently and the belief that such ability would pay higher dividends in the student-directed approach, led to an expectation of a positive effect of study orientation on the student-directed superiority. These anticipated patterns are found if one looks only at selected portions of Figures 2 and 4, but the reversal in the overall pattern is puzzling and we can offer no reasonable substantive explanations.

The current results for the comparison of the student-directed and teacher-directed approaches are compatible with results described in Burkman, Tate, Snyder, and Beditz (1981). This earlier study, based on data from an earlier phase in the same ISIS field test, found for the lowest allocated time considered that the student-directed approach was superior for low abilities and that the extent of superiority decreased with increasing ability. This is the same picture that emerges from Figure 4 when considering variation of the contrast for a constant central study

orientation value of approximately 90 (i.e., moving from left to right on a horizontal line at STUDY = 90). It can be seen from Figure 4 that the addition of the second aptitude of study orientation results, in this case, in strong qualification of the ATI found in the earlier study.

Finally, results for the allocated time variable (under the teacher-directed approach) indicated a disordinal interaction between allocated time and study orientation, with the low time condition superior for high class means on study orientation. The superiority of the high time condition for low study orientation is reasonable and was anticipated. An ordinal rather than disordinal interaction was expected, however, so the reversal of superiority shown in Figure 5 was a surprise and we can offer no reasonable explanation.

In conclusion, several cautions are in order. First, the current findings, of course, apply only to the teachers, students, and settings representative of current ISIS usage. Higher-order interactions with these variables could well produce different conclusions for other populations and settings of interest. Furthermore, it should be remembered that the model used for the current description was not simplified with statistical significance testing, but rather was based on judgements of practical significance using an approach defended in the "Analysis Procedures" section. As explained there, it is hoped that this approach

will be better for identification of interactions in the long run, but it is very possible that some of the interactive features in the current study are due to chance. Thus, they should not be taken seriously until replicated.

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Table 1

Sample Statistics

Treatment	N	ACHIEV $\bar{X}$	ACHIEV S_x	READ $\bar{X}$	READ S_x	STUDY $\bar{X}$	STUDY S_x
SD/LoT	10	59.3	12.0	54.6	14.2	84.3	17.7
GD/LoT	13	56.6	11.4	60.3	15.2	97.7	12.8
TD/LoT	18	53.9	9.8	52.2	10.6	82.6	16.8
SD/HiT	6	62.7	3.9	62.4	5.2	75.3	9.4
GD/HiT	9	58.9	8.1	58.9	7.0	81.0	10.2
TD/HiT	19	57.4	10.7	57.4	10.4	83.1	16.7

Table 2

Treatment Interactive Models[1]

Treatment	Intercept	READ	STUDY	READ x STUDY	R^2
SD/LoT	-39.5	1.485	.794	-.0104	.934
GD/LoT	34.5	.007	-.133	.0058	.846
TD/LoT	36.5	-.064	-.255	.0097	.704
TD/HiT	50.7	.190	-.538	.0085	.729

[1]Table contains unstandardized model coefficients for terms indicated.

Table 3

Interval Estimates for Treatment Contrasts[1]

Contrast	READ, STUDY Combinations 40 , 60	70 , 60	55 , 85	40 , 110	70 , 110
SD - GD (LoT)	1.9 ± 12.7	17.1 ± 15.0	10.4 ± 4.7	15.9 ± 15.3	6.8 ± 11.3
SD - TD (LoT)	0.6 ± 5.0	10.9 ± 9.1	4.4 ± 4.5	12.9 ± 13.7	-7.0 ± 7.0
GD - TD (LoT)	-1.3 ± 13.4	-6.2 ± 15.6	-6.0 ± 4.2	-3.0 ± 10.9	-13.8 ± 11.1
LoT -HiT (TD)	-4.4 ± 8.4	-9.8 ± 9.4	1.7 ± 3.1	12.3 ± 10.8	8.7 ± 12.7

[1]Table entry is 90% simple confidence interval for treatment contrast and aptitude combination specified.

Figure Captions

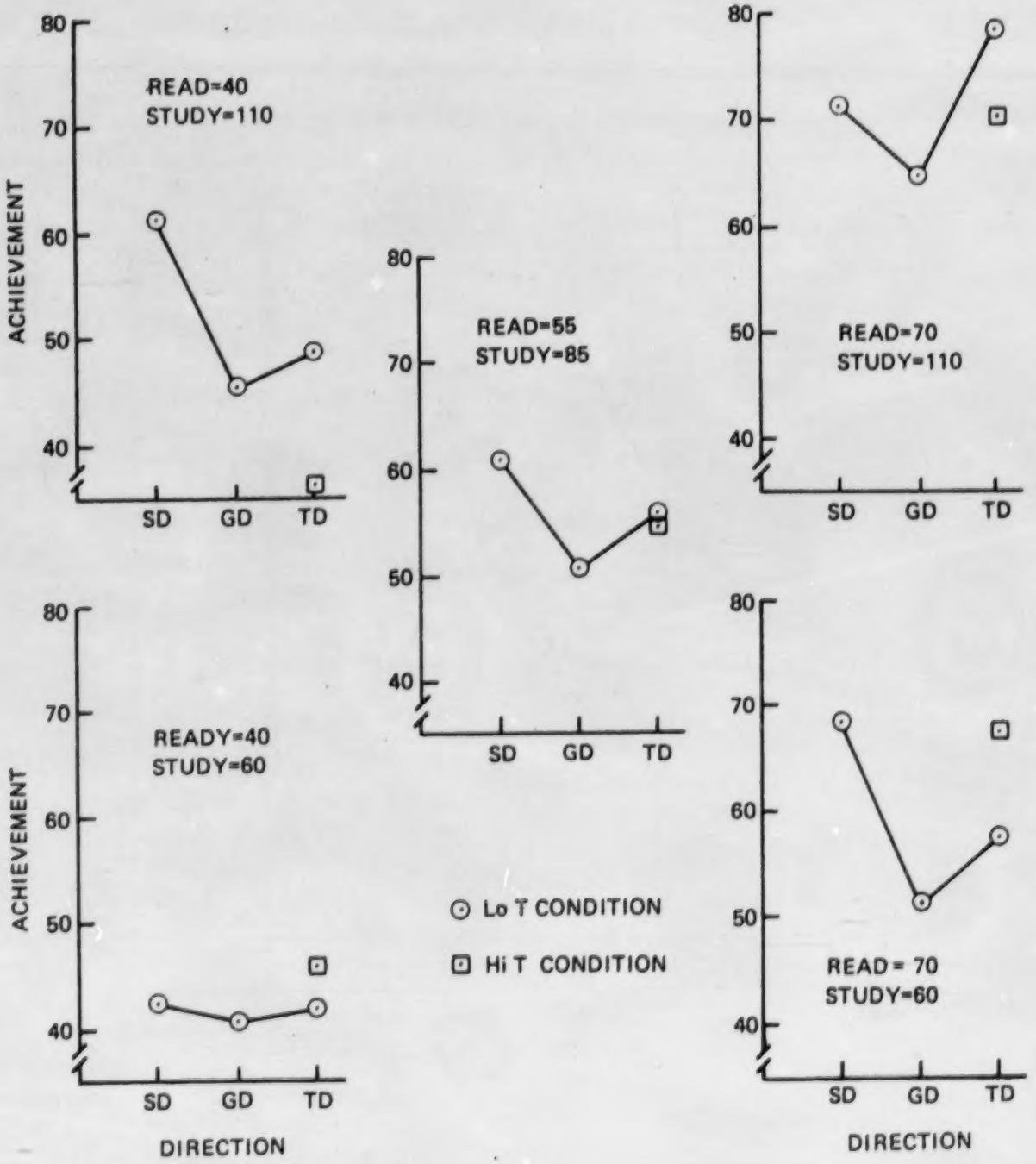
Figure 1. Estimated class achievement patterns.

Figure 2. Student-directed versus group-directed contrast contours.

Figure 3. Teacher-directed versus group-directed contrast contours.

Figure 4. Student-directed versus teacher-directed contrast contours.

Figure 5. Low-time versus high-time contrast contours.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STUDY=110
READ=55
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READ=70
STUDY=110
READY=40
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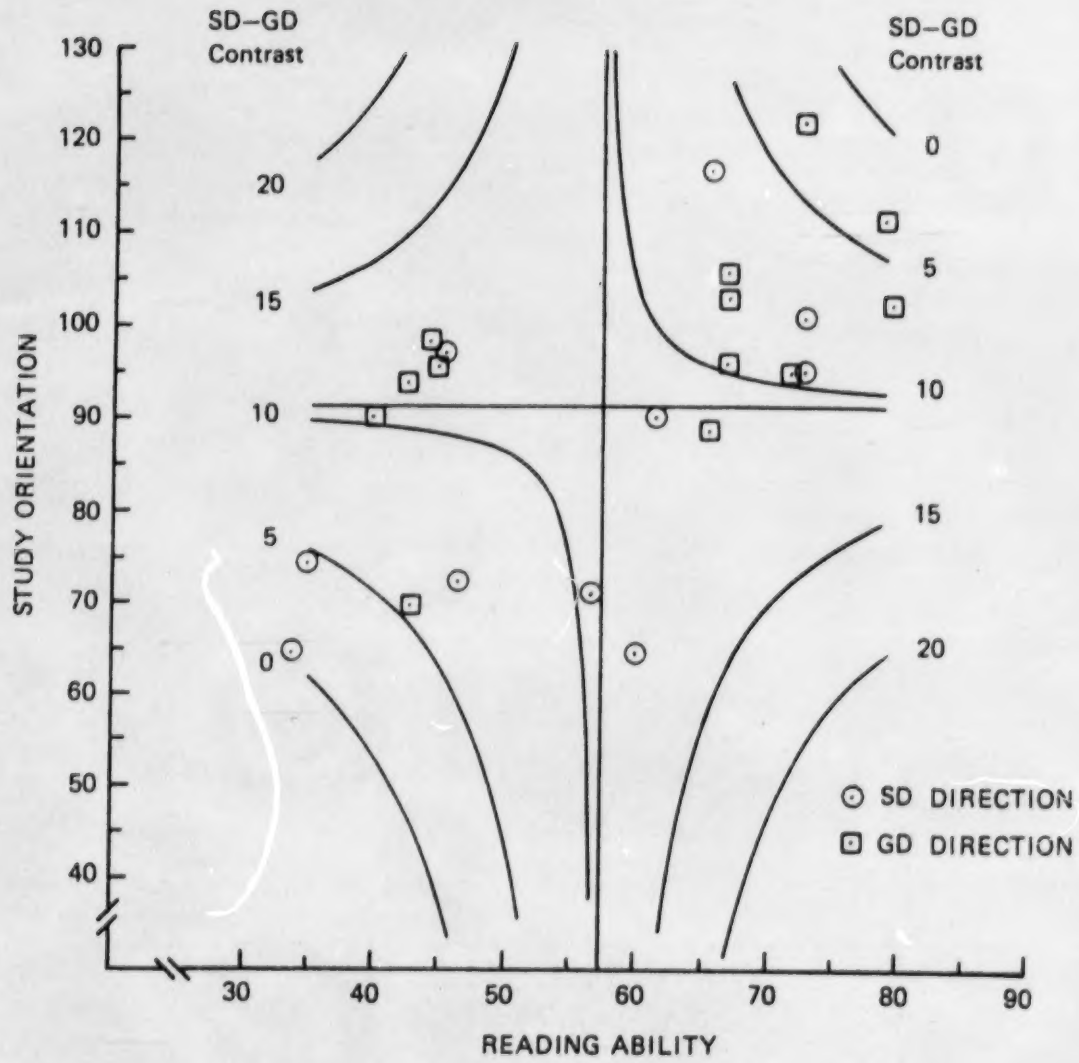
SD–GD
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130
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20
15
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5
0
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STUDY ORIENTATION
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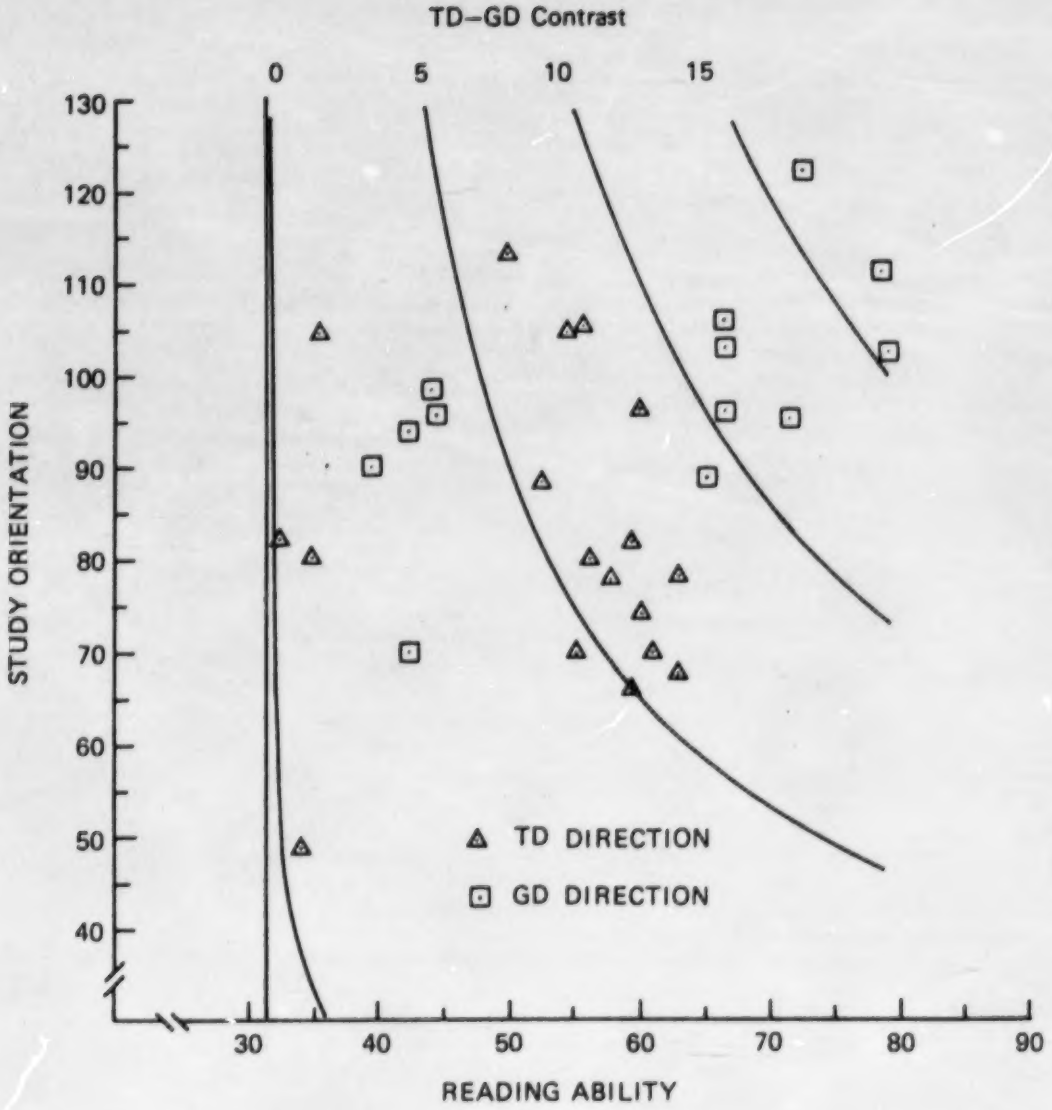
70
80
90
READING ABILITY
SD DIRECTION
GD DIRECTION


TD–GD Contrast
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5
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130
120
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STUDY ORIENTATION
TD DIRECTION
GD DIRECTION
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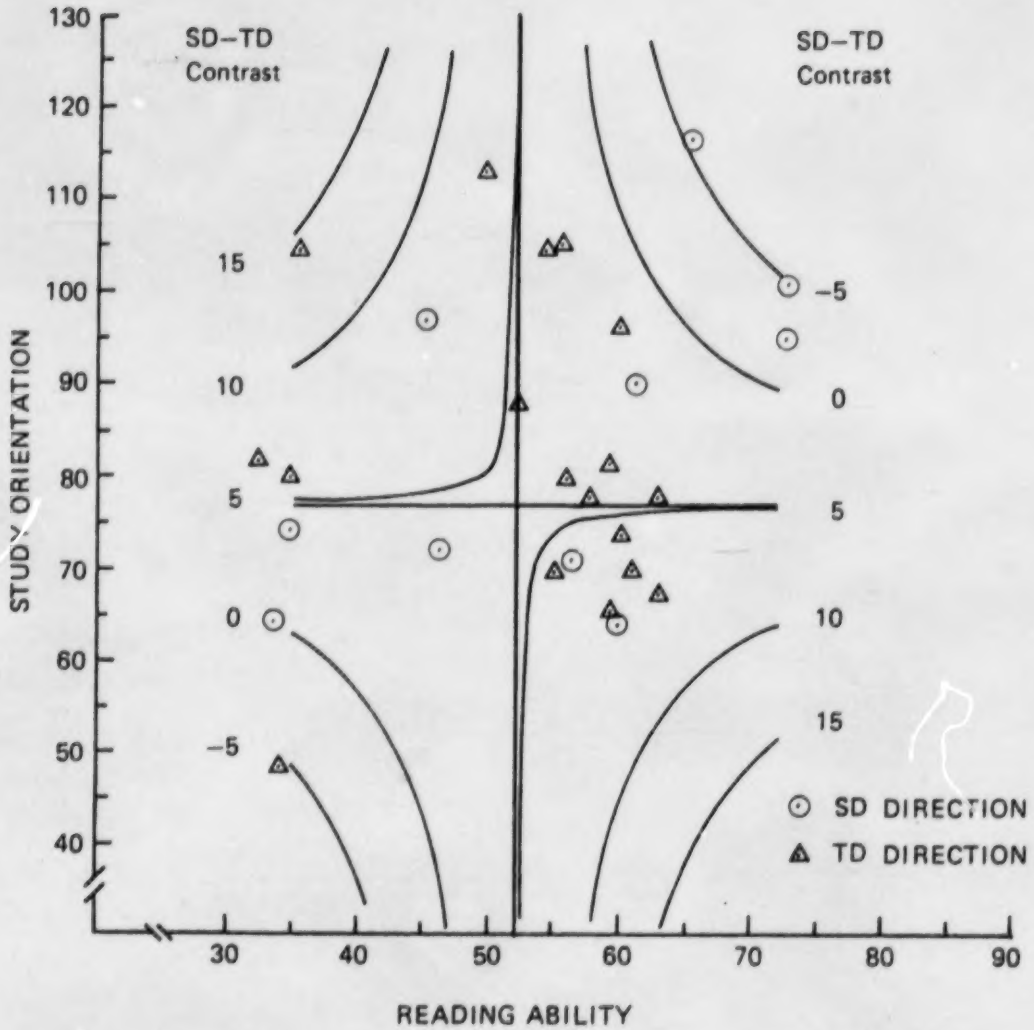
READING ABILITY


SD–TD
Contrast
SD–TD
Contrast
15
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STUDY ORIENTATION
130
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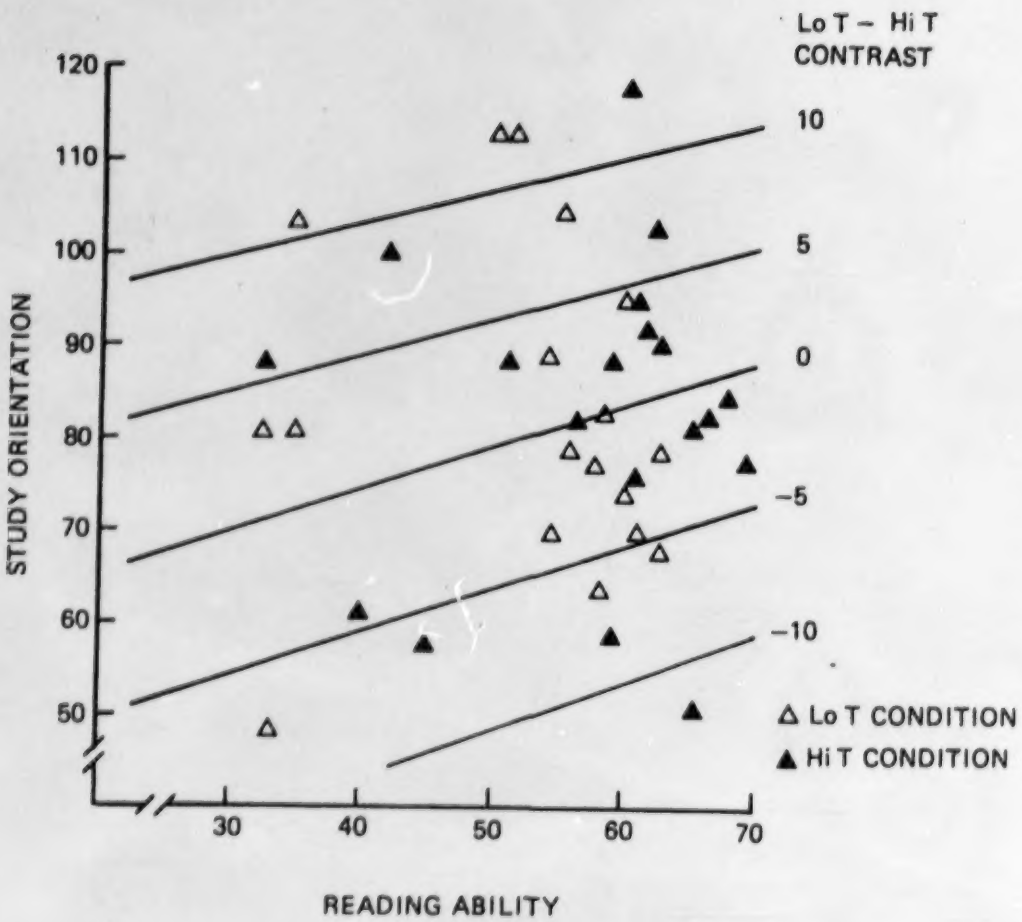
READING ABILITY
SD DIRECTION
TD DIRECTION

4


Lo T – Hi T
CONTRAST
10
5
0
–5
–10
120
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100
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50
STUDY ORIENTATION
30
40
50
60
70
READING ABILITY
△ Lo T CONDITION
▲ Hi T CONDITION

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